COST INDEX FLYING

GRADUATE RESEARCH PAPER

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Abstract

The purpose of this research was to develop new ways of improving aircraft fuel efficiency in AMC by developing cost index equations for the KC-10 and C-17. Although AMC has implemented an aggressive fuel conservation program, it has not yet considered the cost of time with respect to the speeds that its aircraft fly. Specifically, this research sought to answer the feasibility and benefits from using cost index flying, sometimes known as mission index flying. The research questions were answered by first consulting commercial partners and learning how they computed their particular cost indexes. Next, primary data was gathered from the AMC Fuel Efficiency Office and AMC Finance Management Office and was used to develop a cost index equation for the KC-10 and C-17. This cost index was compared to existing commercial cost indexes to test its accuracy. After settling on an accurate cost index equation, the research attempted to compare a "traditional" flight plan profile of a KC-10 and C-17 flying cross-country to a "cost indexed" flight plan profile of the same aircraft and routing. The amounts of fuel used in each profile were compared to demonstrate possible fiscal savings by flying a cost index.

The culmination of this effort found that significant overall operating costs can be reduced by using cost indexing. Recommendations to implement a cost index policy in AMC are discussed.

Acknowledgments

I would like to thank the AMC Fuel Efficiency Office and my academic advisor, Lt Col Doral Sandlin, for their professional guidance throughout this research. I would also like thank Mr. Mitch Dubner of Continental Airlines for taking his precious time and sharing many cost-saving techniques with the U.S. Air Force. Also, Mr. Gary Wagner of Applied Aeronautical Systems, Inc. provided valuable insight into the Cost Indexing program, and the AMC FM Office which provided me valuable cost information. All of these individuals made this research possible.

John M. Mirtich

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I. Introduction

Background

The United States Air Force has proven to be one of the most effective fighting forces in the world. Today, the Air Mobility Command (AMC) has been called on to execute its mission like never before. With budgets extremely tight and operating tempos high, the ability of AMC to continue to deliver on its mission lies heavily in its ability to manage its costs. Therefore, the men and women of AMC are forced to find ways to conduct business more efficiently without losing its great effectiveness.

Like most commercial airlines, the heart of AMC's expenses lies in the cost of aviation fuel. In 2006, and for the first time ever, the cost of fuel in the commercial airline industry accounted for the largest proportion of industry costs (5, 1). In as recent as 2001, the cost of labor in the airline industry accounted for 36.2% of North American airline costs, while fuel comprised a mere 13.4% (5, 1). However, due to rising costs of fuel, the cost of fuel in 2006 accounted for 26.6% of North American airline costs, while the cost of labor comprised only 25.2% (5, 1). In 2008, fuel commanded 32.3% of costs for the commercial airline industry (5, 1).

These trends extend well beyond just the commercial airline industry. Within the United States government, the Department of Defense (DoD) accounts for 91% of all government fuel consumption (1, 4). The U.S. Air Force accounts for 64% of the previous DoD fuel consumption, with aviation accounting for approximately 84% of the Air Force's energy consumption, or about 50% of the DoD's energy consumption (1, 4). The Mobility Air Force (MAF) accounts for the largest portion of AF energy consumption by using 52% of fuel in the AF aviation field, or almost one quarter of the entire DoD energy budget (2, 2).

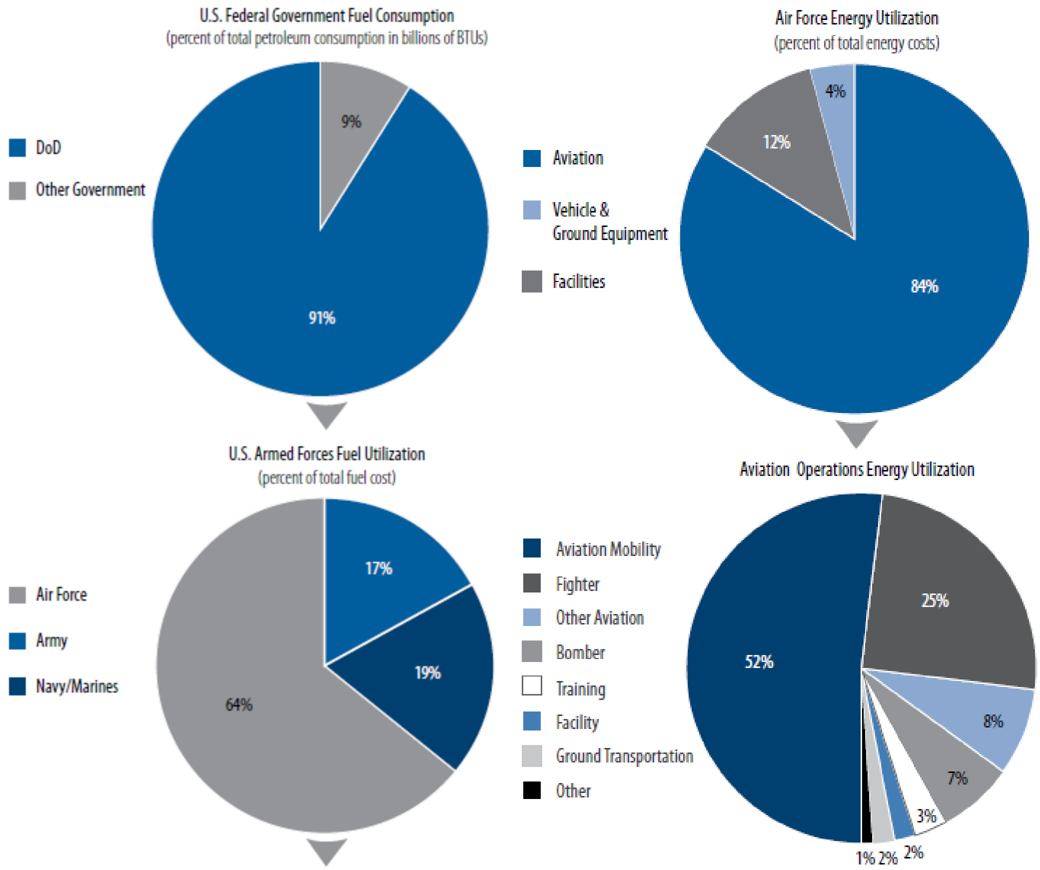


Figure 1. Government and Aviation Fuel Consumption (2, 2)

With budgets getting tighter, and the need to operate more efficiently of utmost importance, the MAF must find ways to increase fuel efficiency and cut overall operating costs. Additionally, in order to meet the AF goal of reducing aviation fuel usage by 10%

by 2015, using 2006 as a baseline, the MAF must utilize every tool possible to take advantage of fuel saving opportunities (2, 5).

In order to help reduce fuel consumption and save on fuel costs, AMC has implemented an aggressive fuel conservation program. This program gives specific fuel conservation direction via aircraft-specific instruction and from publications by the AMC Fuel Efficiency Office (FEO). One fuel-saving measure which has been implemented is lightening aircraft. This was executed by both removing unnecessary items from aircraft and by strictly adhering to planning aircraft fuel loads (6). Most aircraft burn approximately 3% of any extra fuel which is carried for each hour of flight (9, 57). Additionally, aircrews have been directed to fly at optimum altitudes and at Long-Range Cruise (LRC) speeds in order to minimize fuel consumption for a particular flight (8, 5-4). Long-Range Cruise is the speed which gives an aircraft 99% of its maximum nautical miles per unit of fuel (8, 5-4). Although there are multiple ways to gain fuel efficiency in addition to reducing aircraft weights and flying appropriate airspeeds, flying the optimum altitude for aircraft weight is the last significant factor that can be used to increase aircraft fuel efficiency.

Problem Statement

Air Mobility Command has been successful with implementing these concepts of fuel conservation. However, the AF has failed to address the cost of time of flying the aircraft when dictating what speeds an aircraft should fly. The cost of time includes costs to operate the aircraft per unit of time, without factoring the cost of fuel (3, 1). It includes costs such as maintenance, labor, parts, aircrew costs, and support, to name a few (4, 1). It may sometimes be more expensive to fly an aircraft slower at an LRC airspeed versus flying it faster to its destination in order to save valuable time and thus money. For example, if an aircraft costs $10k/hour to operate, it may be more cost effective to fly that aircraft faster to save on very expensive operating costs. The consequence of flying faster would be increased fuel consumption. However, in many cases, the savings gained by reducing operating hours and thus operating costs may outweigh the cost of the extra fuel which was used to fly fast. One tool which must be utilized to help realize these efficiencies is the use of Cost Index (CI) flying.

This report will look in-depth at the problem of reducing MAF fuel consumption by using CI flight planning. Currently, the MAF may not be using the most efficient manner possible to operate its aircraft fleet. In order to maximize both MAF fuel efficiency and minimize overall operating costs, we must find a way to implement cost-savings measures. Cost Index flying may be a viable method of accomplishing this goal.

Research Objectives

In order to develop a method of cost indexing in the AF, it is first necessary to develop the concept behind it. This is initially done by gathering data from commercial airlines to see if they cost index, and if so, how they develop their formulas for particular cost indexes. Once a method for developing a CI equation is learned, an equation will be developed for a particular CI for one of our own AF aircraft. For this research, an equation will be developed using an Air Force KC-10A and a C-17. The KC-10 airframe was chosen due to its similarity with currently flown DC-10 models in the commercial sector (mainly in the commercial cargo aviation sector). If a particular CI is known for its commercial equivalent, then we should be able to obtain similar results with our own CI number to ensure appropriate variables are being considered.

Upon formulation of a particular CI equation, we can then attempt to demonstrate how it might be used in flight planning software for a particular mission. This will provide a great challenge as most CI flight planning is done with the use of advanced computer software, which can balance different variables to compute an optimum CI for a mission. Additionally, the execution of a CI value would require advanced aircraft Flight Management Computers (FMCs) to fully utilize the concept.

After the research is completed, it will be shown that cost indexing is indeed a great way to reduce consumption of aviation fuel in the MAF, and will thus be a valuable tool for reducing overall operating costs.

Research Focus

This research will focus on determining if it's feasible and cost effective to use a CI technique on AF KC-10A and C-17 aircraft missions which are flying either cargo, pre-positioning, or de-positioning legs. The commercial industry has several models using CI which is uses for flights which takeoff, climb to altitude, cruise, then descend to land (3, 10). These types of flight profiles would be similar a KC-10 or C-17 executing one of the above missions. Other types of missions, such as fighter drags or cargo airdrop missions (for aircraft such as the C-17), do not allow the aircrew to fully apply a CI solution to their flight profile. Those profiles would require strict adherence to speeds which may not be mirrored by the CI solution. Using a KC-10 aircraft will allow the comparison of an AF aircraft to one that the commercial industry is also flying. The comparison of like airframes will give a good frame of reference for determining the validity of a KC-10 CI equation.

Methodology

In order to conduct the research, CI information will be obtained from some of the Air Force's commercial partners. Information will be obtained from contacts within Fed Ex, Continental Airlines, and Atlas Airlines to get information on what is going into their CI equations, specifically what operating costs they are using to factor into the cost of time. Multiple companies will provide a better understanding of the diversity of cost indexing by demonstrating how different companies can use different methods to obtain CI values. By examining the commercial inputs to a CI equation, the AF can use similar variables using its own cost figures for the KC-10, and in the future, for all MAF aircraft.

In order to develop an accurate CI equation, data for the operating costs (numerator) will be obtained from the AMC finance management office. This office has determined the hourly costs to operate multiple AF aircraft. The denominator of the equation contains the cost of the fuel. This data will be furnished by the AMC Fuel Efficiency Office (FEO).

Once a particular CI is computed, application of the CI will be the next challenge. It will need to be applied to both flight planning software and individual aircraft Flight Management Systems (FMSs) to be fully utilized. Otherwise, a particular CI number will be nearly meaningless. Therefore, the CI value will need to be translated into something which is usable for flight planning or flying the mission on the aircraft. With this, it will be determined if it's feasible to use a CI with existing AF flight planning software or current aircraft FMSs. After an equation is developed, cost index numbers should be updated when the variables in the equation change. For instance, when the price of fuel changes, CI equations should be recalculated.

Assumptions/Limitations

First, it must be assumed that data obtained from both the commercial and AF sides are accurate and usable. When dealing with the commercial side, a limitation may arise with how much information they are willing to give. Also, it must be assumed that dollar figures obtained from the AMC Finance Management Office are accurate. With inaccurate figures, it will throw off any CI equation and make it unusable. One big limitation will be deciding what factors to use for operating costs (numerator of the equation). There are many different values which could be used, and if large values are chosen for reasons which don't deal with "flying the aircraft," it will essentially eliminate the value of the CI concept. When researching the cost of fuel to be used in the denominator of the equation, the varying cost of fuel at different locations will limit the scope of which we can use to determine an accurate fuel price. Therefore, one fuel price will be chosen, and that fuel price will be used as the assumption for the equation. This will be the same price that is the current contracted price at military installations. The research will, however, demonstrate how varying fuel prices will affect the CI and thus the overall operating costs for an airframe. Additionally, current flight planning capability will limit how a CI solution can be applied to a particular flight profile. By using flight planning software, this report can only rudimentarily compare flight profiles using a CI solution to those which do not. Finally, it must be assumed that the AF would have the technical means to implement and utilize a CI profile.

Implications

Using a CI solution for flights could have a significant effect on the AF and its flight operations. It could drive changes in technology, from new flight planning software to aircraft flight management systems. Using these tools has the potential to reduce MAF fuel consumption by 1 to 2 percent a year, equating to roughly $32.7 million per year in fiscal costs (10). Some possible negative implications include the need to train flight managers and aircrews. Currently, neither flight managers nor aircrews are aware of cost indexing for fuel conservation, and it would require a moderate amount of training to bring everyone up to speed on how to execute it. Additionally, flight managers at AMC would have to be educated and trained on how to implement such a process for mission flight planning. If implemented, flying airspeeds which are slower or faster than normally flown today may cause problems with flight schedules or possibly even with air traffic control. Although a particular flight should be flow at a certain cost indexed airspeed, does not mean that other outside factors will dictate that it's possible to follow the most efficient CI profile.

Literature Review

Historical Perspective

The Cost Index (CI) is the ratio of aircraft time-related costs with respect to the cost of fuel (4, 1). When applied correctly, CI flying can be an effective tool to lower overall aircraft operating costs by determining the most efficient balance of time to fuel for a particular flight.

The CI equation is simply (4, 1):

$$CI = C_T / C_F$$

where

$$CI = \textit{Cost Index}$$

$$C_T = \textit{Cost of Time}\ (\$/\text{hour})$$

$$C_F = \textit{Cost of Fuel}\ (\text{cents/pound})$$

The variables above can be given in different units, depending on which organization is using the CI formulas. This research will use the above units for C_T and C_F.

Factors in the Cost Index

Many factors can make up the numerator of the equation, C_T, otherwise known at the costs of time (minus the cost of fuel) (4, 3). Throughout the airline industry, this value can vary the greatest between different companies. Items such as flight crew wages can have an hourly cost associated with them, or they may be a fixed cost and have no variation with time (4, 3). Engines, auxiliary power units (APUs), and airplanes can be leased by the hour or owned, and maintenance costs on an airplane can be accounted for by the hour, by the calendar, or by cycles (4, 3). As a result, each of these items may have a direct hourly cost associated with them, or be classified as a fixed operating cost.

For the CI equation, only variable costs are used when finding C_T since fixed costs will not vary based on how much time is being put on a particular airframe (4, 3).

In the event an aircraft has high variable direct operating costs, the CI computed will be predictably high, as the airline is trying to minimize expensive flying time by flying fast, and thus minimizing overall operating costs. In the case where most operating costs are fixed, the computed CI will be low, thus emphasizing a more fuel efficient profile since fuel is going to dominate the overall operating costs.

The denominator of the equation, C_F, otherwise known as the cost of fuel, is much simpler. This value is simply the cost of fuel in cents per pound. This value, however, can vary based on concepts of fuel hedging, tankering fuel to locations where fuel is more expensive, or differences in fuel contracts between organizations (4, 3). One can see that the cost of fuel at a location can significantly alter the CI which is computed for a particular aircraft on a specific route.

Cost Index Examples

The range of computed cost indexes can range anywhere from 0-9999, depending on the aircraft manufacturer or airframe model (4, 2). In theory, the accounting sections of a company would compute the CI for a particular airframe then pass the value to the flight planning sections, which would apply the appropriate CI to an individual flight plan. Without the use of flight planning software and aircraft flight management systems (FMS), a particular CI value may not have much meaning to a person. However, one can formulate that a CI=0 will minimize the use of fuel; flying at maximum range and having no consideration for the cost of time (minimum trip fuel) (4, 1). Conversely, a maximum CI would indicate that time is valuable and that the aircraft will be planned to fly as fast as possible within performance limits, thus having no consideration for the amount of fuel burned (minimum trip time) (4, 1). In reality, the actual CI flown will most likely lie somewhere in between the two extremes. The chosen CI will depend on many factors, including flexibility of time, fuel prices at a location, or company goals. The following CI chart is designed for the Airbus 300/310 aircraft (3, 10). One can observe that if the cost of time is high, and the cost of fuel is medium, then a CI=80 is computed. This number will balance the high cost of time and moderate cost of fuel to optimize the overall operating cost of the flight. Once computed, the CI will be input into both flight planning software to develop the flight plan, and the aircraft FMS which will notify the crew as to what altitudes and airspeeds they need to fly to optimize the CI profile.

Table 1. Airbus 300/310 Cost Index (3, 10)

(kg/min)
(Honeywell FMS)

TIME COST (US$/min) / FUEL COST (US$/USG)	LOW < 15	MEDIUM 15 < to < 20	HIGH > 20
LOW < 0.7	**65**	**85**	**100**
MEDIUM 0.7 < < 0.9	**50**	**65**	**80**
HIGH > 0.9	**40**	**55**	**65**

Boeing recently conducted research of a particular unnamed airline as to what cost indexes they were currently flying for their 737 and MD-80 aircraft versus the most efficient CI (4, 3). The results compare the airlines' current cost index to the optimum cost index and then translated the differences into flight time and dollars saved for a typical 1000-mile trip (4, 3). One can see that in all cases, flying the optimum CI has a very small penalty to time (normally less than 3 minutes per 1000-mile trip), but saves a large amount of fuel (4, 3). Over the course of one year, it was estimated that this airline could save between $4-5 million in overall operating costs (4, 3).

Figure 2. Boeing Cost Index Impact (4, 3)

FLEET	CURRENT COST INDEX	OPTIMUM COST INDEX	TIME IMPACT MINUTES	ANNUAL COST SAVINGS ($000's)
737-400	30	12	+1	US$754 – $771
737-700	45	12	+3	US$1,790 – $1,971
MD-80	40	22	+2	US$319 – $431

Executing a Cost Index

Once a CI has been computed by company accounting offices, flight planners will input the computed CI into flight planning software which will build a flight plan based on the ratio of the CI (3, 57). This ratio will adjust the aircraft speeds, altitudes, and route to balance the costs of time and fuel that the computed CI dictates. This CI number is then input by the aircrew into the aircraft FMS, which will dictate to the crew optimum climb speed, optimum altitude, optimum cruise speed, and optimum descent speed (3, 57). These airspeeds may vary based on temperatures and winds, and the aircraft FMS will adjust these speeds accordingly.

Flywize Flight Planning System

Atlas Airlines currently uses a flight planning system called "Flywize" to flight plan and mangage its aircraft missions of Boeing 747-200 and 747-400 aircraft (16). This flight planning system is an "all-encompassing" system which considers cost indexing and other factors. In actuality, the system is designed to optimize flying operations across the board, not by only using cost indexing. The cost indexing portion of the flight planning system analyzes all possible routes (both vertical and horizontal) by factoring in winds, temperatures, and route restrictions (13, 8). Additionally, it will compute optimum step-climb profiles (13, 8). The system is also capable of optimizing payload management, considers critical fuel scenarios, exercises delay cost management, considers overflight charges, as well as fuel cost management and tankering solutions (13, 8).

When considering the cost of time, C_T, portion of the CI equation, Flywize uses the variables of time dependent maintenance cost, crew cost, overflight charges, and forcast or actual delay cost (13, 3). The costs of fuel, C_F, are used in the denominator of the equation and considers tankering fuel to destinations where fuel may be more expensive (13, 3). In this scenario, an aircraft may elect to takeoff with a greater full load than needed to execute a mission. This will result in a higher fuel burn, and thus a higher fuel cost for that particular flight leg. However, the goal is to save on uploading fuel at an expensive location. Landing with extra fuel (within aircraft operating limits) decreases the fuel needed to be uploaded at the destination. Overall, when considering multiple legs on missions, it will result in overall lower operating costs.

The following chart demonstrates potential cost savings that Flywize has computed using a fleet of 30 aircraft, 10 flying short, 10 flying medium, and 10 flying long-range missions (13, 7). More specific cost savings analysis can be obtained from the company and then be used to calculate possible savings for an entire aircraft fleet.

Figure 3. Example of Airline Savings Potential (13, 7)

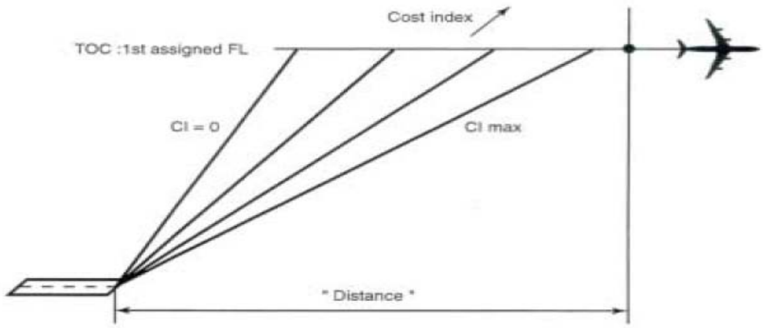
		Short Range	Medium Range	Long Range	Total
Number of A/C		**10**	**10**	**10**	**30**
Legs/Day		**6.0**	**3.0**	**1.5**	
Legs/Year		**21900**	**10950**	**5475**	**38325**
Opt. Module		**Short Range**	**Medium Range**	**Long Range**	**Total**
FL	**X**	157,680	361,350	985,500	$1,504,530
Mach	**X**	407,340	367,920	1,642,500	$2,417,760
Stat COF	**X**	109,500	219,000	438,000	$766,500
Route	**X**	0	657,000	1,314,000	$1,971,000
Overflight (**)	**X**	47,125	99,348	380,577	$527,050
Delay Mgmt	**X**	657,000	1,642,500	1,368,750	$3,668,250
Tankering	**X**	438,000	438,000	465,375	$1,341,375
Total ($) Saving Potential (as a Δ from current operating costs)					$12,196,465

Within the AF, cost benefits will most certainly be different. For example, some of the cost savings won't be realized within categories such as overflight charges or delay management. However, it can be seen that great benefits can be gained in the other categories. Since the entire fleet of MAF aircraft far exceeds the number of aircraft in the above example, annual savings could be far greater than the $12 million saved using the previous number of aircraft (10).

Cost Index in the Climb

Once a CI is computed, the aircraft FMS will dictate a climb speed based on the environmental conditions and the computed CI, called "Econ Climb" (3, 20). Below is an example of how CI can be applied to aircraft climb and descent profiles (3, 20).

Figure 4. Cost Index Climb Profile (3, 20)

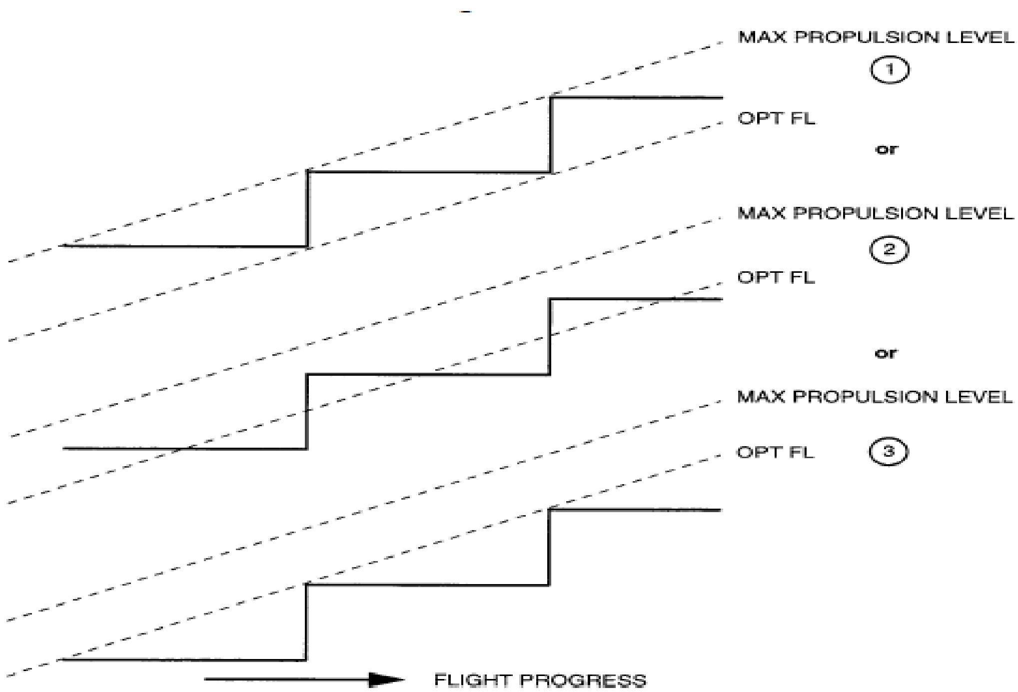


Notice that a CI=0 commands a “best rate of climb” profile, thus using a slower airspeed and getting to the fuel efficient cruise altitude in minimum time. When the CI is increased towards the maximum, the aircraft executes a shallower climb (higher speed), has a longer climb distance, and has a farther Top of Climb (TOC) (3, 20).

Cost Index for Optimum Altitude

During a climb, the aircraft FMS will compute the optimum aircraft cruise altitude. Without a CI profile, an aircrew would generally choose one of three level-off and step-climb profiles (3, 27). Contrary to popular belief, it is not more beneficial to level-off at an altitude higher than optimum altitude. The following table demonstrates the benefits of following a more fuel efficient climb profile. This figure dictates that it is best for economy to level-off and stay close to the optimum altitude versus climbing a little above the optimum (3, 27).

Figure 5. Step-Climb Profiles (3, 27)



- **best order for improved manoeuvrability margins : 3, 2, 1**
- **best order for money saving economy : 2, 3, 1**

This same concept can be applied to the AF KC-10. The KC-10 performance manual indicates that crews may climb to an altitude which is 2000 feet above optimum altitude, thus utilizing a 4000-foot step-climb profile (8, 5-4). Therefore, without data indicating penalties for flying off of optimum altitude, many crews figured that it was most fuel efficient to fly at a higher altitude. However, the figure below shows how much range is sacrificed in the KC-10 by flying off of optimum altitude. This figure uses a 420,000 lb. aircraft, flying at a speed of 0.82M, and the optimum altitude of 35,000 feet (7, 39).

Table 2. DC-10-30 420,000 Pounds vs. 0.82 Mach Cruise at 35,000 feet (7, 39)

ALTITUDE (FT)	LBS/NM.	LBS/NM % CHANGE	CRUISE FUEL $ COST/AC/YR*	INCREASED $ COST/AC/YR
OPT + 2000	36.18	2.002	2,452,000	48,100
OPT (35,000)	35.47	0	2,403,900	—
OPT-2000	35.72	0.705	2,420,800	16,900
OPT-4000	36.94	+ 4.144	2,503,500	99,600
OPT-6000	38.54	+ 8.655	2,611,900	108,000

*Comparison based on fixed distance of 1,135,200 NM resulting from 0.82 M (473 TAS) at 35,000' for 2,400 hrs. per A/C per yr. Actual cruise time will vary with TAS for 0.82 M at off optimum altitudes.

Although the above cost figures are in "1978 dollars," it is easy to see how much money could be saved by simply having a program which computes your optimum altitude and directs climbs to future optimum altitudes as aircraft weight decreases with time. In this example, it is shown that chosing to fly an altitude which is only 2000 feet higher than optimum, aircraft range is decreased by 2% (7, 39). In this case, it is shown that if not able to climb to optimum altitude (if ATC restricted), leveling at an altitude slightly below optimum is most economical. In an era where every pound of fuel is valuable, and every percent saved is critical, losing 2% off of range by flying off of optimum altitude is quite expensive.

Cost Index Cruise Application

Upon level-off, flying the optimum CI value should lie somewhere between Maximum Range Cruise (MRC) and Long Range Cruise (LRC) airspeeds. These definitions are often synonymous with 100% max range and 99% max range airspeeds, respectively. As aircraft gross weight, outside air temperatures, or winds change, the given cost index may slightly change aircraft speed. However, the computed speed for a given CI will still fall between MRC and LRC airspeeds (4,2).

Commercial Application

Most, if not all, airlines utilize the cost index concept in daily operations. However, the method by which they develop and implement their programs may differ significantly. Research with FedEx found that they use a CI=65 for their MD-10 aircraft (the near-equivalent of the Air Force KC-10) (15). This number is derived by using FedEx-specific information in the numerator the CI equation. Typical components of C_T used by FedEx are aircraft lease rate (amortized over an assumed amount of hours/month), maintenance spares and support on a per hour basis, and crew costs (15).

Continental Airlines, on the other hand, uses a simpler model for determining its C_T. Hourly crew costs and variable maintenance costs ($/hour) are the only inputs that comprise the cost of time (14). Research results using multiple flight plans for a Continental Boeing 777 are shown below (14). The route flown is a one-way flight from Houston, Texas, to London-Heathrow. Notice should be given to the different flight times, fuel burn, and overall operating costs.

Table 3. Continental Airlines Boeing 777 Flight Profiles (14)

Method	Trip Fuel	Fuel Cost (cents/lb.)	Fuel Cost ($)	Flight Time (hrs)	Flight Cost ($/hr)	Cost of Time	Total Cost	
CI 100	147200	41.1	60469	9.75	1500	14625	75094	
CI 50	146100	41.1	60017	9.96	1500	14940	74957	Best
CI 30	145900	41.1	59935	10.07	1500	15105	75040	
CI 20	145900	41.1	59935	10.12	1500	15180	75115	
CI 10	145900	41.1	59935	10.18	1500	15270	75205	
CI 0	146000	41.1	59976	10.25	1500	15375	75351	
.85 Mach	152300	41.1	62564	9.4	1500	14100	76664	Worst
.84 Mach	149600	41.1	61455	9.52	1500	14280	75735	
.83 Mach	148300	41.1	60921	9.63	1500	14445	75366	
	Price ($/Gal)	**Price (cents / lb.)**		**CI Computed**				
	2.74	41.1		37				

This chart demonstrates the fuel savings that are made possible by operating a CI flight profile. Notice that all of the “fixed Mach” profiles carry higher overall operating costs than any of the CI profiles. If not on a CI profile, this aircraft would be flying a fixed Mach of 0.84 (14). However, Continental choses a CI=30 for this flight and is able to save approximately $788 for the flight. When applying CI profiles to daily operations of 400+ flights, operating cost savings can exceed $100k on a daily basis, depending on route profiles and abilities to use a CI profile.

II. Methodology

This research will first focus on current emphasis that commercial airlines have for flying via a CI. Since the airlines are businesses which need to make money to remain viable, it is imperative that they operate in the most efficient overall manner, not just operating fuel efficiently. This research examines how different airlines use the CI method and how each airline computes its CI equations. After it is learned how the commercial industry computes its particular cost indexes, this research look at how we can use similar techniques to develop a CI equation for AF aircraft. Mostly, this will require an in-depth look at how operating costs other than the cost of fuel are computed.

Since there are many diverse aircraft type throughout both the commercial and military sectors, this research will focus on an airframe that is flown both in the civil sector and in the Air Force. Now, commercial CI values can be used in comparison to values that would be expected by computing our own formula. For this reason, the commercial DC-10 (currently flown with FedEx as an MD-10) will be compared with the current AF KC-10. This way, similar aircraft qualities and costs should be relatively alike, and will thus result in obtaining a KC-10 CI value which is similar to the value used by FedEx.

Next, the research will give a formula which can be used operationally to develop a specific CI value. Without the proper computer flight planning software or aircraft FMS which is capable of deciphering a particular CI, having a value will be of limited use. Broad generalizations will be able to be made by the resulting CI value, but in order to reap the true benefits of a CI flying, it should be applied with the appropriate computer systems. This research will crudely demonstrate how CI could work with appropriate flight planning systems. However, the capability to alter flight profiles and routing will not be possible to emulate without access to the software.

Finally, this research will demonstrate how the concept of cost indexing could save AMC millions of dollars each year. In the end, by optimizing the hourly operating costs versus the cost of fuel, AMC can realize an overall reduction in operating costs.

III. Results and Analysis

Calculating the Cost of Time, C_T

Research with commercial carriers found that all used some sort cost indexing in order to save on overall operating costs and maximize profit. FedEx used a fixed CI of 65 for its MD-10 fleet (15). However, other airlines used variable numbers based on the flight profile. These CI numbers would be developed well prior to the flight to satisfy as many company requirements (i.e. schedule, fuel consumption, flight time, etc.) as possible.

Using the commercial models, we were able to develop a cost index equation for the KC-10. The biggest challenge was computing the cost of time, C_T. In order to compute an accurate CI value, we first had the find accurate hourly operating costs for the KC-10. After consultation with both the AMC FEO and the finance management office, it was concluded that the best measure of “other operating costs” would be to use the “Variable Costs – Total Aircraft Inventory (TAI)” for the calendar year (11). The variable costs capture those operating costs which are variable dependent on how many hours the aircraft is flown. For the Air Force, this includes variable maintenance costs, logistics costs, but not crew costs (11). Fixed costs are ignored since they have no impact on the overall operating cost of a particular flight. One good example of a variable maintenance cost is the cost to lease the aircraft engines on the KC-10. Since the engine lease is based on a specific amount of operating time on each engine, this cost is directly affected by aircraft operating time.

One variable cost which is incorporated into a commercial CI equation is the hourly crew cost. For this research, since military aircrew are paid fixed salaries, it is assumed that aircrew costs are fixed for any particular mission. It is acknowledged that in rare cases, flying CI profiles could create slightly higher Temporary Duty (TDY) costs. However, additional crew TDY costs would happen so infrequently, it would be counter-productive to factor it into the CI equation. Therefore, unlike the commercial carriers, it is not feasible to add aircrew costs into the equation.

Subsequently, the Variable Operating Cost value was found to be: $193,721,783 (11). This fiscal value then needed to be converted into an hourly operating cost per aircraft. Since all 59 KC-10 aircraft were flown a total of 71,514 hours during the 2009 calendar year, this value equates to an hourly cost of $2709 per hour (11). Unless other abnormal factors are introduced, this research will use a C_T value of $2709/hour to be used in the numerator.

Calculating the Cost of Fuel, C_F

As witnessed on a daily basis, the cost of fuel can be highly variable in today's economy. This is no different in the aviation industry. However, there are certain measures in place to help create a more stable and predictable price of fuel for the DoD. Normally, this is done through the creation of fuel contracts. Currently, in fiscal year 2011, the DoD pays $3.03/gal of fuel at military installations (12). In fiscal year 2012, this value is expected to be $3.12/gal (12). However, this price is not necessarily paid at each location the DoD visits. Therefore, a variable price of fuel can greatly affect the CI equation for a particular flight. For example, if fuel only costs \$3.12/gal, the CI may direct the aircraft to fly at a relatively fast airspeed since fuel isn't grossly expensive. However, if the cost of fuel were \$6.50/gal as it is in NATO locations, the CI would dictate a lower number, thus slowing down aircraft speed to minimize consumption of \$6.50/gal fuel (12).

The average motorist experiences this concept on a daily basis when deciding which gas station they should use to fill their car. If a motorist is given inexpensive fuel, they will likely not give as much care to their fuel efficiency. However, when gas prices soar, many are concerned about driving as efficiently as possible. Therefore, in order to capture the majority of cases and to minimize confusion, this study will use the forecast rate for FY 2012 of \$3.12/gal for the price of fuel in the CI denominator when computing the KC-10 CI example(12). However, in reality, varying fuel prices will continually alter applicable cost indexes.

Computed KC-10 Cost Index Equation

Using the dollar figures given above, our CI equation reads:

$$CI = C_T / C_F$$

$$CI = \$2709/hr\ /\ 46.8\ cents/lb.$$

$$\boldsymbol{CI = 58}$$

This value is similar to the value of 65 that FedEx uses to fly their MD-10 aircraft (15). However, it is important to remember that as each company uses different factors in their variables, each will compute a different CI. Additionally, without the proper flight planning and FMS software, this computed value may be nothing more than a number. Being able to apply and execute the number is arguably just as important.

The next step in the CI process would be to plug the CI value into appropriate flight planning software. Appropriate flight planning software will be able to balance the cost of time versus the cost of fuel to get the optimum overall operating cost of the flight. It will calculate a favorable routing based on winds, temperature and diplomatic clearances. Next, it will compute the altitudes and airspeeds that should be flown in order to follow the CI profile. This is done starting in the climb phase thru cruise and finally descent phases. Additionally, the aircrew would have the capability to plug the CI value into either their aircraft FMS or possibly a laptop computer that will help fine tune optimum aircraft altitudes and airspeeds. Without the final two steps of utilizing flight planning software and aircraft CI capability, computing a value is of little use. KC-10 CI flight planning software is currently in development, so this research uses traditional software to demonstrate potential savings, which is a limitation.

In order to demonstrate a rudimentary CI flight, a computer flight plan (CFP) was computed from Hickam AFB, HI, to McGuire AFB, NJ. This routing was chosen because it offers a relatively long flight time, which will better demonstrate cost differences over time of flying different airspeeds. Additionally, it demonstrates a typical mission profile that would use a CI. This flight could easily be a pre-positioning, de-positioning, or a cargo sortie. The airlines have demonstrated effective cost indexing when using it with these types of sorties.

Table 4. KC-10A Flight Profiles

Method	Trip Fuel	Fuel Cost (cents/lb.)	Fuel Cost ($)	Flight Time (hrs)	Flight Cost ($/hr)	Cost of Time	Total Cost
.84 Mach	135,782	46.8	63,514	8.82	2,709	23,892	87,406
.83 Mach	132,654	46.8	62,051	8.92	2,709	24,163	86,214
.82 Mach	131,039	46.8	61,296	9.02	2,709	24,434	85,730
.81 Mach	130,156	46.8	60,883	9.13	2,709	24,732	85,615
.80 Mach	130,202	46.8	60,904	9.23	2,709	25,003	85,907
.82/350	136,480	46.8	63,841	9.13	2,709	24,732	88,573
	Price ($/Gal)	**Price (cents / lb.)**	**Variable Costs (TAI) ($)**	**Total Hours**	**Variable Costs / FH**	**Cost Index Computed**	
	3.12	46.8	193,721,783	71,514	2708.87	58	

This table demonstrates a limited capability with regards to current flight planning software. In this case, it is impossible to tell what speeds, altitudes, or routing that a CI of 58 would dictate. It can be seen that a CI of 0 would be flown at 0.81 Mach. This equates to MRC speed in the KC-10 (lowest trip fuel). A high CI would drive speeds of 0.85 Mach or greater. Consequently, interpolation could be used to find where CI of 58 would fit. In this case, it would fall somewhere between 0.81 and 0.82 Mach. It is important to note that the flight planning software used could not take advantage of optimum routings based on winds, nor could speeds and altitudes be optimized based on outside air temperatures and exact aircraft weights. This is a software limitation.

Therefore, this method leaves much room for improvement with respect to flight planning and aircraft systems which could lower overall operating costs.

Projected Savings for a Single Mission

If a more advanced flight planning program had been used to plan the flight in the previous example, it is feasible that approximately 1% of fuel could have been saved or approximately 1,300 pounds. This equates to approximately $610 of operating costs which could be avoided. If able to apply to even a small portion of MAF flights on a daily basis, the savings would be substantial.

Computed C-17 Cost Index Equation

One critical component of Air Force logistics that will greatly alter a CI equation is the type of logistics support that an airframe receives. The two main types of logistics support are either organic, such as the KC-10, or Contract Logistics Support (CLS), such as the C-17. Under CLS, a contract will be written for a fixed price to support a fixed amount of flying hours. In the case of the C-17, AMC contracts support for 150K flying hours annually (17). This causes many of the variable costs which were seen in the KC-10 example to shift to fixed costs in the C-17 example. Decreasing variable costs will drive lower overall CI values since aircraft are not as concerned about saving airframe time, unless the fleet is in an “overfly” scenario and is charged hourly “penalties” for overflying.

Since most of the C-17 costs are fixed and the cost of fuel resides in the denominator of the CI equation, only four aspects of support remain which are variable based on airframe time. These items and their associated costs are as follows (17):

Aircrew Temporary Duty Costs: $117/hr

Consumables: $142/hr

Fly Depot Level Repairable: $358/hr

Non-Flying Aviation Fuel, Oil and Lubricants: $11/hr

Overall, when adding all of the variable cost items, the overall variable cost to operate the C-17 equates to $628/hour (17). When using this value in a CI equation, the equation reads:

$$CI = C_T / C_F$$

$$CI = \$628/hr / 46.8 \text{ cents/lb.}$$

$$\boldsymbol{CI = 13}$$

As previously discussed, this value is much lower than the KC-10 CI simply because many of what would be variable costs for the KC-10 are all rolled into the CLS contract with the C-17.

C-17 Cost Index Application

Once a CI equation is created and the sortie goal is determined, the appropriate CI value can be input into the Advanced Aeronautical Systems, Inc. (AASI) Mini-Flightplan (MFP) system. This system "overlays" a legacy flightplan with routing and meteorological conditions which are manually input then optimizes the flight time and fuel burn to minimize overall operating costs. In this case, the same routing from Hickam AFB, HI, to McGuire AFB, NJ, was used. The following table shows different CI values and their associated flight times, fuel burn profiles and overall operating costs. These inputs were found by building the MPF, then inputting different CI values to find the fuel burn and flight times. Depending on the goal of the sortie, any of these CI values could be chosen and used in the flight planning process.

Table 5. C-17 Flight Profiles

Method	Trip Fuel	Fuel Cost (cents/lb.)	Fuel Cost ($)	Flight Time (hrs)	Flight Cost ($/hr)	Cost of Time	Total Cost
.74 Mach	128,491	46.8	60,104	9.25	628	5,809	65,913
CI 0 (min trip fuel)	126,436	46.8	59,142	9.65	628	6,060	65,203
CI 13 (opt)	126,499	46.8	59,172	9.55	628	5,997	65,169
CI 25	126,613	46.8	59,225	9.48	628	5,953	65,179
CI 50	126,880	46.8	59,350	9.43	628	5,922	65,272
CI 100	128,537	46.8	60,125	9.23	628	5,796	65,922
CI 300	136,122	46.8	63,673	8.9	628	5,589	69,262
CI 500	145,925	46.8	68,259	8.7	628	5,464	73,722
CI 2000 (min trip time)	168,957	46.8	79,032	8.52	628	5,351	84,383
	Price ($/Gal)	**Price (cents / lb.)**			**Variable Costs / FH**	**Cost Index Computed**	
	3.12	46.8			628	13	

It can be seen that the current procedure of flying a "fixed Mach" of 0.74 yields an overall operating cost of $65,913 for the Hickam to McGuire sortie. However, many CI profiles exist which could lower overall operating costs. For instance, if this aircraft were de-positioning and flight time was not of concern, flight managers would plan this sortie at a CI = 13. This would result in overall operating costs of $65,169, which saves $744 over the fixed Mach profile. If fuel prices increased from $3.12/gal to $3.50/gal, this would drive flight managers to a CI = 11 and would create a slightly increased flight time over the CI = 13 profile, but would save on fuel burn.

In the case where the cost of fuel is the only concern, the sortie would be planned at a CI = 0, which results in the lightest fuel burn scenario of 126,436 pounds of fuel while saving $710 in overall cost over a fixed Mach profile. However, it should be noted that flying a CI = 0 results in flying slower airspeeds, thus increasing the flight time by 6 minutes in this scenario. Conversely, if fuel burn was not a factor and speed was of critical importance, the aircraft would be planned at the maximum CI value, resulting in minimum trip time. This method saves a little more than 30 minutes of flying time, but results in fuel costs which are approximately $20K greater than fuel-efficient profiles.

Finally, a realistic scenario might be one in which the aircraft is dictated to arrive at McGuire at a particular time. In this instance, the aircrew would be able to operate the MPF system and input a Required Time of Arrival (RTA). Doing this would simply drive the MPF to compute a flight time to meet the RTA, thus computing a CI to fly based on the RTA. For example, if it was determined that the RTA would require a flight time of no more than 9 hours, then MFP could calculate that this would require a CI = 300 in order to meet the timing restriction. In doing so, it would create the most economical profile under the given time constraint.

Often times, especially when crossing large bodies of water or in non-radar environments, aircrews operate in airspace where climbs to optimum altitudes may be restricted or denied. In cases such as these, mission planners must plan adequate fuel on board to account for a scenario where the aircrew is not granted the most fuel efficient altitude which they have requested. In these cases, the MFP system can be very beneficial as it will constantly provide optimum airspeeds for the crew as aircraft weight decreases. In particular, as aircraft weight decreases, the optimum airspeed for a particular CI value will also decrease. At low CI values, the speed reduction will be significant. For a CI = 0 profile, given a constant altitude of 35,000 feet, aircraft speed decreased from its initial cruise speed of 0.74M all of the way to 0.64M. This speed reduction was necessary for the most fuel efficient burn. However, as CI values increase, the speed adjustments decrease. For a CI = 13 profile, the speed adjustment went from 0.74M at initial level off to 0.68M just prior to descent. For a CI = 2000 profile, speed was not adjusted. The following table demonstrates the ability of the AASI MFP system to reduce costs even when the most efficient profile is unavailable due to uncontrollable circumstances.

Table 6. C-17 Flight Profiles at 35,000 Feet

Method	Trip Fuel	Fuel Cost (cents/lb.)	Fuel Cost ($)	Flight Time (hrs)	Flight Cost ($/hr)	Cost of Time	Total Cost
.74 Mach	132,524	46.8	61,990	9.2	628	5,778	67,768
CI 0 (min trip fuel)	128,011	46.8	59,879	9.92	628	6,230	66,109
CI 13 (opt)	128,075	46.8	59,939	9.8	628	6,154	66,094
CI 50	129,049	46.8	60,365	9.53	628	5,985	66,350
CI 100	130,980	46.8	61,268	9.3	628	5,840	67,108
CI 200	135,379	46.8	63,326	9.03	628	5,671	68,997
	Price ($/Gal)	**Price (cents / lb.)**			**Variable Costs / FH**	**Cost Index Computed**	
	3.12	46.8			628	13	

In cases such as the one above, aircrews would be able to take given time or altitude restriction and let the computer develop a profile which is most efficient. In this altitude restricted example, $1674 in overall cost reduction could be obtained by utilizing a CI tool.

IV. Discussion

Today's fiscal environment creates multiple challenges in the Air Force. These challenges are especially important in the MAF, where the volume of fuel consumed is so substantial. However, the volume of fuel consumed also gives AMC and the MAF aircraft the greatest potential for savings. One way in which the MAF can help save money is to implement a cost index flying program. This program would not only help save on aviation fuel costs, but it would also help reduce overall operating costs. Since the MAF consumes approximately 25% of the entire DOD energy budget, the AMC cannot afford to not implement a cost savings program which is proven to save money industry-wide.

Cost indexing is a simple and effective tool when used appropriately. If AMC implements a program with inaccurate variables with respect to either the C_T or the C_F, the program could create cost penalties. This is especially important when figuring how to calculate the cost of time. These cost penalties would most likely apply to overall operating costs, and not just fuel consumption costs. Therefore, it is important to be as accurate as possible when assessing the costs of "flying the airplane."

When used appropriately, cost index numbers will dictate particular routing based on winds and temperatures, climb and descent rates and speeds, optimum flight levels, optimum times to execute a step-climb, and cruising speeds, all dependent on the CI value which was computed. It must be noted that the computed CI may not always be the most optimum with respect to cost. Instead, it will compute the most optimum CI value under a given set of constraints. This would be realistic when either Air Traffic Control (ATC) or scheduling constraints prevent operation at overall optimum cost indexes. Future innovations in more efficient ATC systems could further allow for even greater flight efficiencies.

Today, the AF needs to find ways to be more fiscally responsible. By investing a reasonable amount of money into flight planning and aircraft flight management systems, AMC has the opportunity to lead the way in overall cost savings.

Blue Dart Submission Form

First Name: __John___________ Last Name: _ Mirtich___________

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[ ] core values	[X] command	[ ] strategy
[ ] war on terror	[ ] culture & language	[ ] leadership & ethics
[ ] warfighting	[ ] international security	[ ] doctrine

[ ] other (specify): ____

Suggested Headline: __Cost Index Flying_________________________________

Keywords: __Cost Index Flying, Mission Index Flying, Fuel Consumption, Overall Operating Cost_
{*e.g., leadership, ethics, Nuremburg, Giessen, intimidation, chain of command*}

The United States Air Force has proven to be one of the most effective fighting forces in the world. Today, the Air Mobility Command (AMC) has been called on to execute its mission like never before. With budgets extremely tight and operating tempos high, the ability of AMC to continue to deliver on its mission lies heavily in its ability to manage its costs. Therefore, the men and women of AMC are forced to find ways to conduct business more efficiently without losing its great effectiveness.

Like most commercial airlines, the heart of AMC's expenses lies in the cost of aviation fuel. In 2006, and for the first time ever, the cost of fuel in the commercial airline industry accounted for the largest proportion of industry costs. In as recent as 2001, the cost of labor in the airline industry accounted for 36.2% of North American airline costs, while fuel comprised a mere 13.4%. However, due to rising costs of fuel, the cost of fuel in 2006 accounted for 26.6% of North American airline costs, while the cost of labor comprised only 25.2%. In 2008, fuel commanded 32.3% of costs for the commercial airline industry.

These trends extend well beyond just the commercial airline industry. Within the United States government, the Department of Defense (DoD) accounts for 91% of all government fuel consumption. The U.S. Air Force accounts for 64% of the previous DoD fuel consumption, with aviation accounting for approximately 84% of the Air Force's energy consumption, or about 50% of the DoD's energy consumption. The Mobility Air Force (MAF) accounts for the largest portion of AF energy consumption by using 52% of fuel in the AF aviation field, or almost one quarter of the entire DoD energy budget.

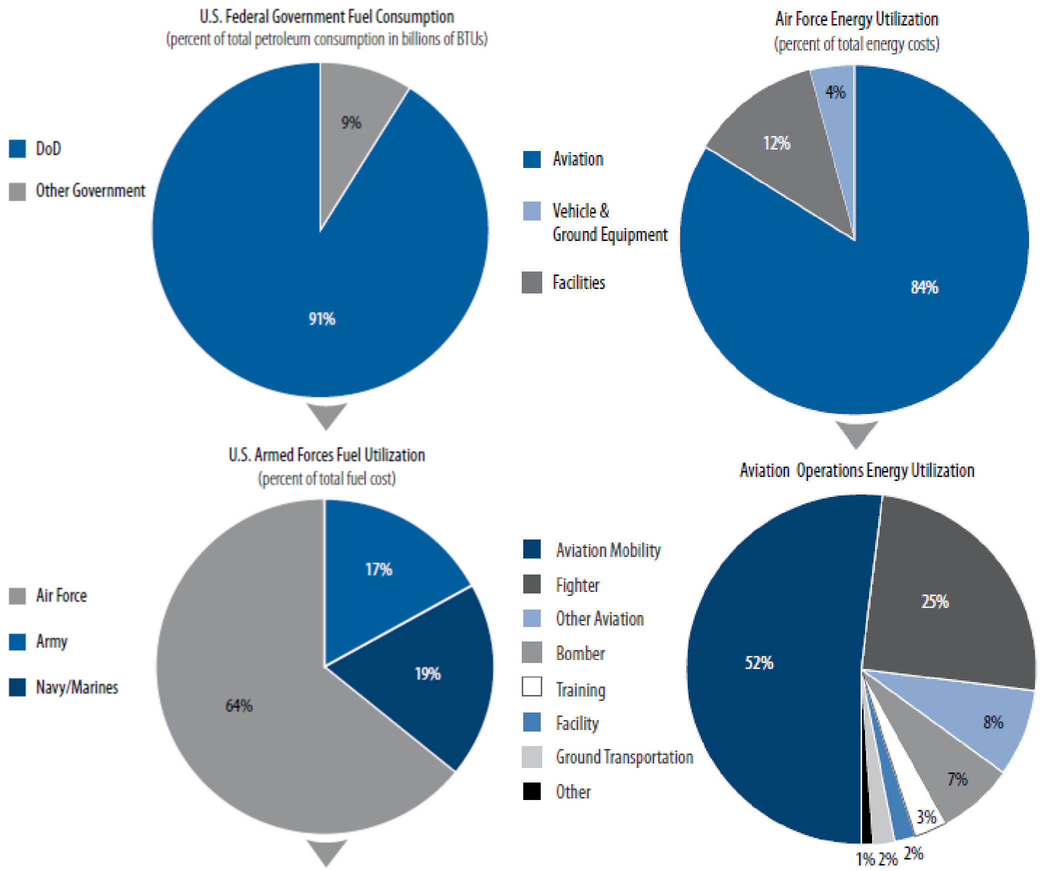


Figure 1. Government and Aviation Fuel Consumption

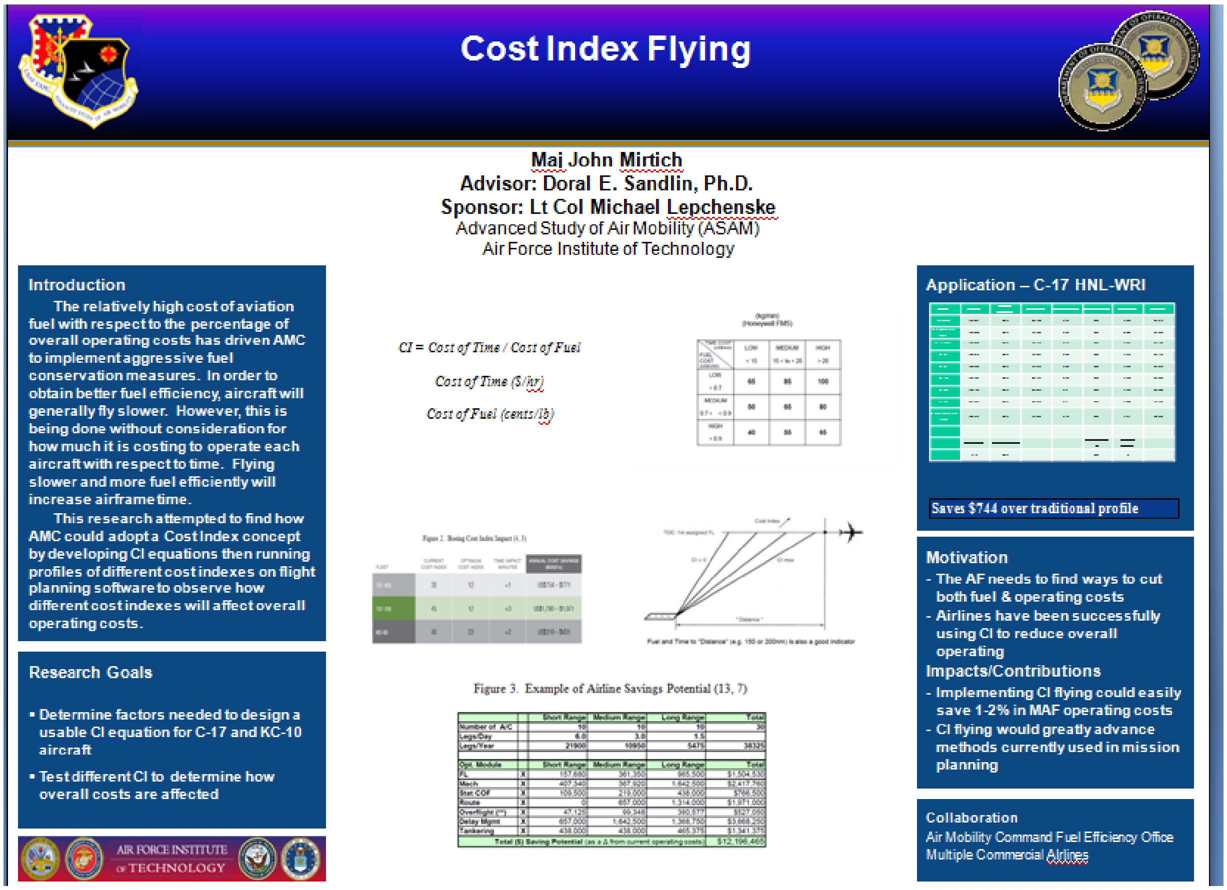
With budgets getting tighter, and the need to operate more efficiently of utmost importance, the MAF must find ways to increase fuel efficiency and cut overall operating costs. Additionally, in order to meet the AF goal of reducing aviation fuel usage by 10% by 2015, using 2006 as a baseline, the MAF must utilize every tool possible to take advantage of fuel saving opportunities.

In order to help reduce fuel consumption and save on fuel costs, AMC has implemented an aggressive fuel conservation program. This program gives specific fuel conservation direction via aircraft-specific instruction and from publications by the AMC Fuel Efficiency Office (FEO). One fuel-saving measure which has been implemented is lightening aircraft. This was executed by both removing unnecessary items from aircraft and by strictly adhering to planning aircraft fuel loads. Most aircraft burn approximately 3% of any extra fuel which is carried for each hour of flight. Additionally, aircrews have been directed to fly at optimum altitudes and at Long-Range Cruise (LRC) speeds in order to minimize fuel consumption for a particular flight. Long-Range Cruise is the speed which gives an aircraft 99% of its maximum nautical miles per unit of fuel. Although there are multiple ways to gain fuel efficiency in addition to reducing aircraft weights and flying appropriate airspeeds, flying the optimum altitude for aircraft weight is the last significant factor that can be used to increase aircraft fuel efficiency.

Air Mobility Command has been successful with implementing these concepts of fuel conservation. However, the AF has failed to address the cost of time of flying the aircraft when dictating what speeds an aircraft should fly. The cost of time includes costs to operate the aircraft per unit of time, without factoring the cost of fuel. It includes costs such as maintenance, labor, parts, aircrew costs, and support, to name a few. It may sometimes be more expensive to fly an aircraft slower at an LRC airspeed versus flying it faster to its destination in order to save valuable time and thus money. For example, if an aircraft costs $10k/hour to operate, it may be more cost effective to fly that aircraft faster to save on very expensive operating costs. The consequence of flying faster would be increased fuel consumption. However, in many cases, the savings gained by reducing operating hours and thus operating costs may outweigh the cost of the extra fuel which was used to fly fast. One tool which must be utilized to help realize these efficiencies is the use of Cost Index (CI) flying.

This report will look in-depth at the problem of reducing MAF fuel consumption by using CI flight planning. Currently, the MAF may not be using the most efficient manner possible to operate its aircraft fleet. In order to maximize both MAF fuel efficiency and minimize overall operating costs, we must find a way to implement cost-savings measures. Cost Index flying may be a viable method of accomplishing this goal.

Appendix B. Quad Chart



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14. ABSTRACT
The purpose of this research was to develop new ways of improving aircraft fuel efficiency, thus reducing overall operating costs in aviation for the Air Force. Specifically, this research sought to answer the feasibility and benefits from using cost index flying. The research questions were answered by first consulting commercial partners and learning how they computed their particular cost indexes. Next, primary data was gathered from the AMC Fuel Efficiency Office and AMC Finance Management Office and was used to develop a cost index equation for the KC-10 and C-17. This cost index was then used in advanced flight planning software to compare overall operating costs.

15. SUBJECT TERMS
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